TECHNICAL REPORT NO. LWL-CR-02F70

DIRECTIONAL LIGHT, PYROTECHNIC

Final Report

By

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The U.S. Army Land Warfare Laboratory developed a Directional Pyrotechnic Light for use during night ambushes and other selected combat and noncombat uses. That design used an expedient candle made from two M127A1 Signal Candle Assemblies placed end to end to burn sequentially. Adaptation of these candles for use in the light required extensive modifications which were time consuming, expensive and hazardous.

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A one-piece candle was designed and fabricated which reduces manufacturing time and costs, is less hazardous to produce, and is compatible with and adaptable to standard industry manufacturing processes and procedures.

The Directional Light has been tested, demonstrated, and, as a result, judged suitable for field evaluation.

FOREWORD

The Pyrotechnic Directional Light was developed for the U. S. Army Land Warfare Laboratory, Aberdeen Proving Ground, Maryland. Work was performed under terms of the following contracts:

Design Feasibility
Contract No. DAAD05-72-C-0209
Work Assignment 11

Fabrication and Test
Contract No. DAAD05-73-C-0543

The work performed under these contracts included development of the one-piece candle for the Pyrotechnic Directional Light, production engineering of the mechanical components, testing, and fabrication of a quantity of units for delivery.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

During a development program in 1970-71, LWL developed a Pyrotechnic Ambush Light and shipped 200 to RVN for field evaluation by RVNAF in mid 1971. This effort is described in LWL Technical Memorandum No. 71-03, August 1971. As a result of a favorable evaluation, USARV recommended type classification after determination of optimum performance characteristics and a U.S. Army need.

The objectives of this program were to redesign the Pyrotechnic Directional Light, incorporating a one-piece candle; to fabricate 130 units, complete with shields and packaging; to test 20 and deliver 110 for evaluation by U.S. Army units.

Development work on the improved unit began with the fabrication of a one-piece candle. Effort in this area consisted of development techniques for blending and compacting the flare ingredients as well as establishing end cap and ignition component design. Requirements in this phase of work were that the candle performance should not be degraded and that it should fit the existing unit without extensive unit modification.

Redesign of the mechanical components of the directional light consisted mainly of adapting the housing and related components to the new one-piece candle. Hazardous and unacceptable manufacturing and assembly processes were also revised for safety and simplification. Changes were incorporated into the flare housing, the shield tube and the base plug, which had been dangerously spot welded into place after assembly of the pyrotechnic material.

DESIGN

Throughout the development of the one-piece Pyrotechnic Directional Light certain design requirements governed all considerations:

1. The Pyrotechnic Candle shall have a minimum output of 125,000 candlepower and minimum burn time of one minute.

2. Maximum ignition time, from actuation of M57 Firing Device to full light output, shall be .5 seconds.

3. The candle should operate within the constraints of paragraphs 1 and 2 at $+145^{o}F$ and $-50^{o}F$.

4. Changes to the Pyrotechnic composition, ignition and first-fire elements shall be kept to a minimum consistent with design and performance requirements.

5. The Pyrotechnic Candle shall be designed:

   a. To withstand rough handling tests MTP 4-2-602 including the 7 foot Packaged Drop Test, Loose Cargo Test and the 5 foot Drop Test, with a subsequent Performance Test.

   b. To pass waterproofness test (immersion and spray)

6. Integrate the one-piece candle into the system with minimum changes to the system.

7. Design the systems to reduce manufacturing time and costs, increase manufacturing safety and to be compatible with and adaptable to standard industry manufacturing processes and procedures.

DEVELOPMENT

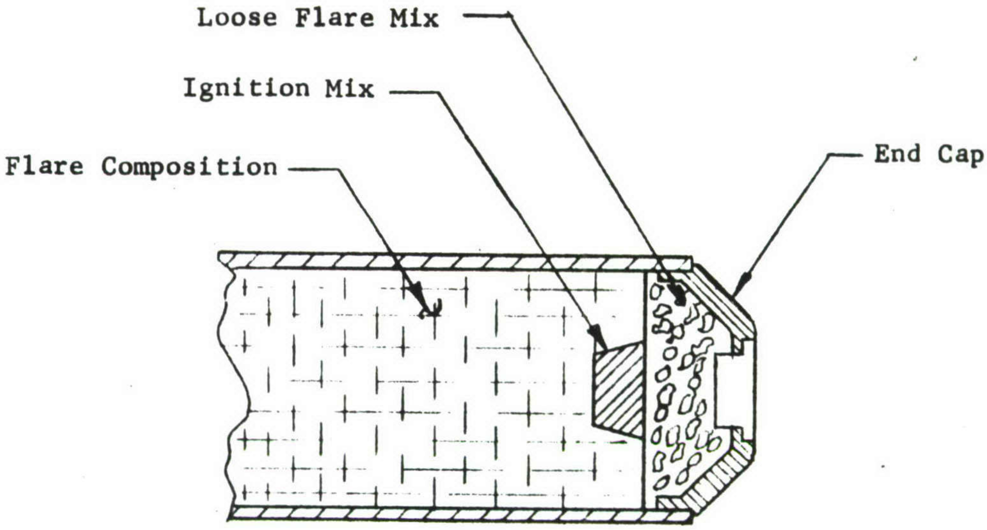
Development work on the one-piece Pyrotechnic Directional Light began with the investigation of blending and compaction techniques of the flare composition. The ingredients for the flare composition are listed in Table 3, page 16. It was discovered that unless these materials were combined in the proper sequence, the resulting composition could deteriorate in that there could be a severe separation of ingredients. If the binder material is added after blending the magnesium and sodium nitrate, the sodium nitrate will slurry and not adhere sufficiently to the magnesium granules. The proper sequence for blending the flare ingredients is to blend all fuel ingredients first; magnesium, Pluronic (wetting agent) and Laminac (fuel-binder). Then, after the magnesium is throughly wetted with binder, the oxidizer, sodium nitrate, is added and blended to a uniform consistency.

Initial attempts at compacting the flare composition were conducted using a cured and dried composition at 4,000 psi ram pressure, pressing 50 gram increments. Using this assembly process, it was possible to load only 180 grams of flare composition in the available volume. Because the resulting burn time was inadequate to meet design requirements, it was necessary to investigate means for loading more composition into the flare cartridge. The required amount of flare composition, 200 grams, was pressed into the available volume after being advised to press the flare composition while still damp, and increase the ram pressure to 8,000 psi. Also, the composition was pressed in sixteen 12.5 gram increments. Burn times of 58 to 74 seconds were obtained after the modification to the original procedure.

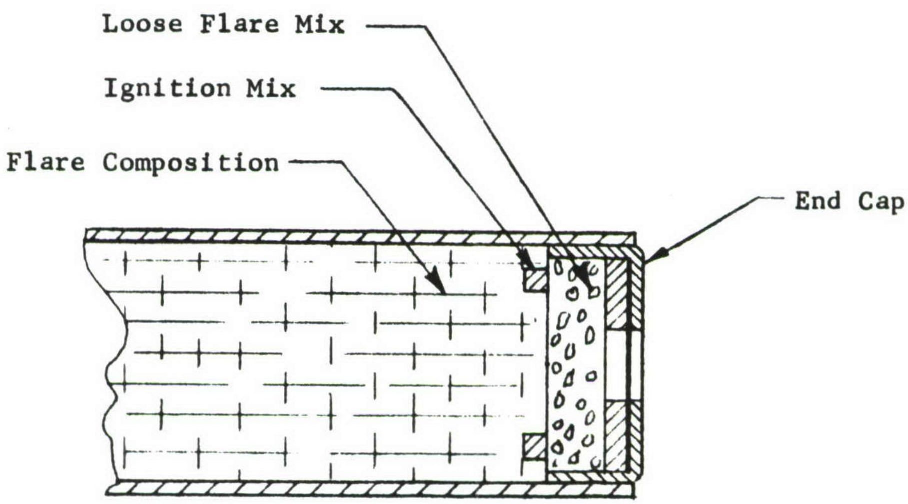
The end cap design was altered due to ignition and packaging requirements, and increased length of the flare composition. Modification of the end cap as shown in Figure 1, enables the assembly to extend into the rib area of the shield for packaging storage. The tapered section also contains the volume required for ignition materials.

While considering operations that could be eliminated or improved, it was decided that waterproofing of the unit might be accomplished through sealing the end cap with RTV rather than packaging the entire flare cartridge in a plastic bag. This revision provoked some ignition problems, but proper restraint between the end cap and the flare sleeve was all that was required to obtain reliable ignition. The units were subjected to waterproofness tests several times more than were required without any visible evidence of leakage through the end cap.

The largest cost improvement achieved in the redesign of the hardware was in the modification of the shield assembly. Redesign of the shield tube to a one piece machined sleeve eliminated many costly operations both in manufacturing

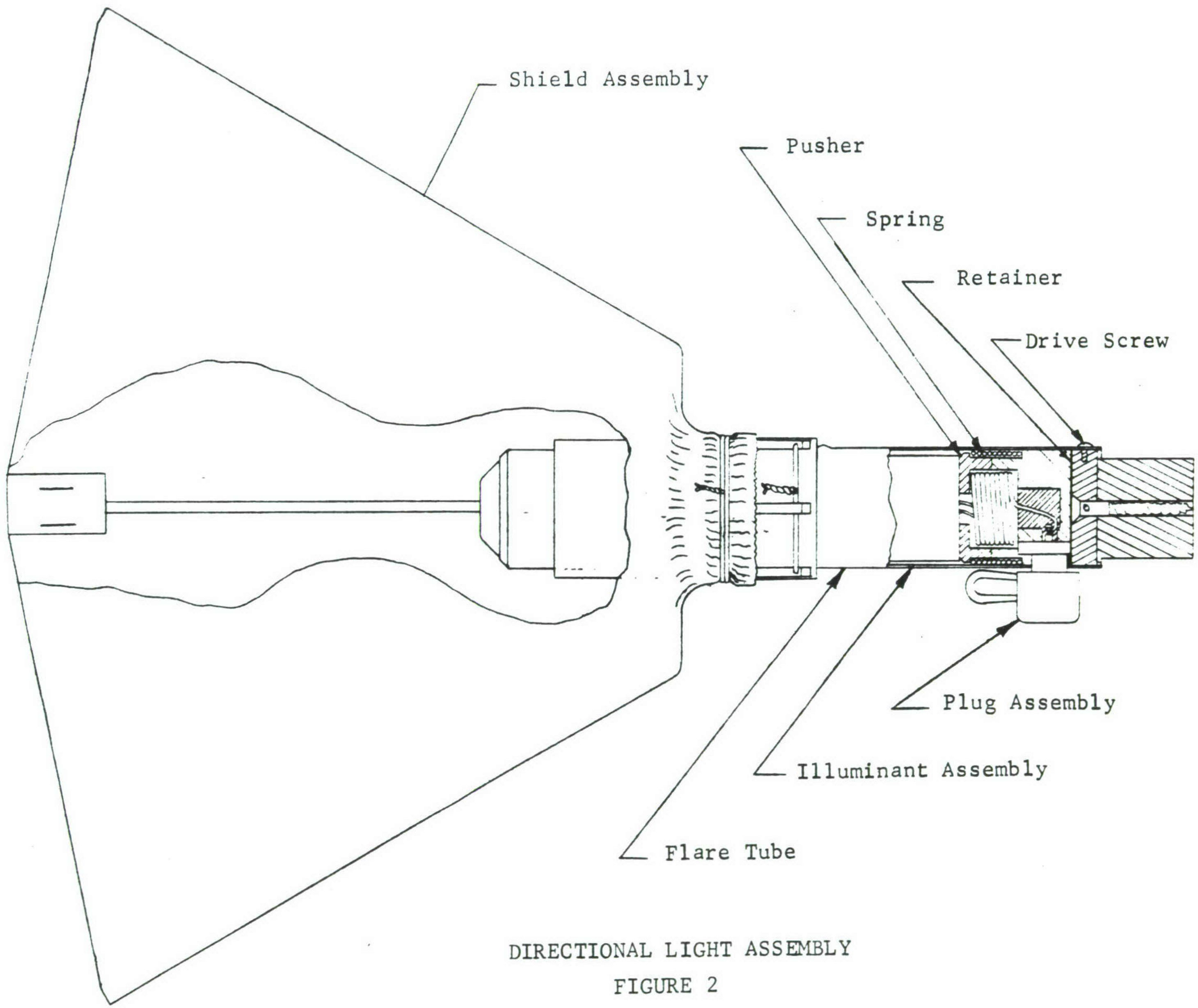


END CAP, ONE-PIECE CANDLE



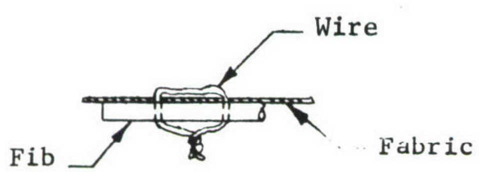
END CAP, TWO-PIECE CANDLE

FIGURE 1

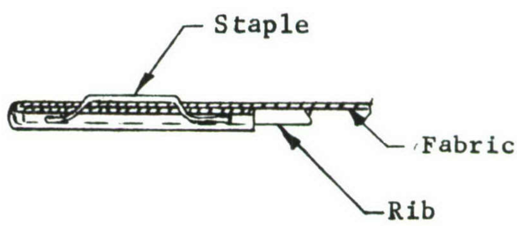


DIRECTIONAL LIGHT ASSEMBLY
FIGURE 2

and assembly. Previously, the shield tube was fabricated of seven formed sheet metal parts which were drilled to accommodate a wire hinge and then spot welded together on a jig to form a single unit. Assembly of the shield ribs to the shield tube was accomplished by positioning the ribs in the axial slots provided in the shield tube, threading the hinge wire through the drilled holes in the shield tube and ribs, and then twisting the wire ends together to secure the components in position. The redesigned shield tube is machined from an aluminum tube which requires only five axial slots and two circumferential grooves to complete the finished item (one groove is narrow to receive the hinge wire and the other wider to serve as an attachment point for the shield assembly). To assemble the shield ribs, wire is threaded through the hinge hole in the five ribs. The ribs are then placed in the axial slots provided in the shield tube and positioned so that the hinge wire lies in the narrow circumferential groove. The hinge wire ends are then twisted together to secure the assembly. Assembling the shield fabric to the shield tube was accomplished in the same manner in the new design as on the old, but anchoring to the shield ribs was accomplished differently. In the previous design, holes were provided in the end of the shield ribs through which wire was threaded, then laced through the fabric and the wire ends then



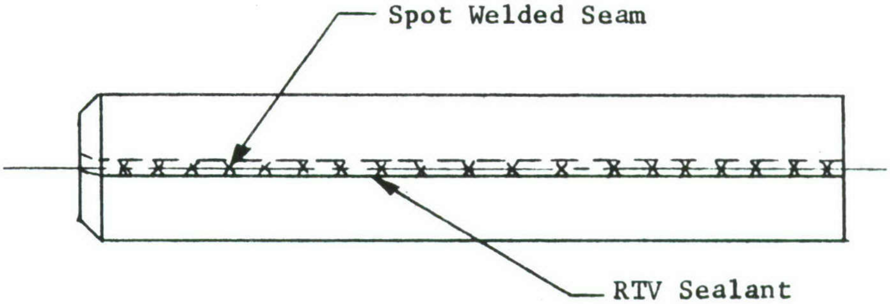
RIB END, WIRE ASSEMBLY



RIB END, STAPLE ASSEMBLY

twisted to fasten the assembly. The improved design eliminated the necessity for additional holes and lacing wire. A tab or extension was added to the shield fabric which, when folded in and stapled, formed a pocket for the ribs which contained them satisfactorily.

Another cost improvement incorporated into the final design was the use of seamless stainless steel tubing for the flare tube replacing the tube which was formed from a flat sheet, spot welded on the seam and sealed with RTV.



WELDED FLARE TUBE

Because of safety requirements the end cap assembly was redesigned. Originally, the end cap consisted of a metal cup with a wood screw extending through and brazed to the center of it. This assembly was then spot welded to the flare tube after all other components were assembled inside of the flare tube. This meant that a potentially hazardous unit was being spot welded which was an absolutely unacceptable process. To remedy this condition, the end cap assembly was fabricated using a Delrin disc which was drilled and countersunk to receive a wood screw. The Delrin disc and wood screw were then assembled, drilled and pinned. To complete the final assembly, the base plug was then fastened to the flare tube with drive screws in place of the original spot welding process.

TEST

Initial ignition and burn time tests were conducted employing a test fixture, consisting of a flare tube housing, spring and pusher, which simulated the function of the complete unit. Instead of feeding the M100 electric match leads through the base of the unit and connecting internally, they were fed through the end cap opening of the flare tube and connected to firing leads externally.

To eliminate some of the waterproofing problems, a solid, tapered end cap was used in the early test firings of the one-piece candle in place of the end cap with a hole that was previously used. Burn times of 60 seconds were not obtainable using this design although modifications were made to the flare composition and the ignition components. Upon returning to the end cap configuration containing the hole, burn times of 60 seconds were obtained. An adhesive backed vinyl disc was used as a waterproof closure and paper wadding was used as a filler inside the cap. At this point only 2.5 grams of loose flare mix were used for ignition, and wadding was required to maintain initimate contact between the electric match and other ignition elements. This front end construction functioned properly with numerous burn tests, but failed to give reliable results during the first series of waterproof tests. Evaluation of the problem resulted in filling the end cap entirely with loose flare mix to assure there would be flammable substance in contact with the electric match under all conditions. Also, to improve ignition, greater restraint was provided on the end cap so that the heat generated by the electric match would impinge on the ignition components for a longer period of time.

Twelve units of this design were tested, including three subjected to waterproofing tests and all fired satisfactorily, except for the loss of a few seconds in burn time. Results of these tests are listed in Table 1, page 14. Twelve complete Directional Light units and four dummy units were then assembled and packaged for Rough Handling Tests per MTP4-2-602. The seven foot packaged Drop Test required that the units be subjected to extreme temperatures prior to drop. Six units were conditioned at $+145^{o}F$ and six were conditioned at $-50^{o}F$. Three units at each temperature were dropped on end, and the remaining units were dropped base down. The crates were labeled with the mode of test so that the same position and temperature would be used for the respective units during the Loose Cargo Test. Following the Loose Cargo Test, which was performed by General Environments Corp., Springfield, Virginia, Appendix A, the units were returned to AAI for the unpackaged 5 foot Drop Test and function test which was witnessed by the Project Officer from LWL.

Prior to the five foot unpackaged Drop Test and Function Test, six units were conditioned at +145°F and six units were conditioned at -50°F. Results of the functional tests are listed in Table 2, page 15. Three of the six units conditioned at -50°F failed to light although ignition of the electric match caused the end cap to open. Since the Directional Light was not tested at temperatures lower than -32°F previously, it is obvious that functional difficulties could not be foreseen the first time at -50°F. Possibly, the problem could be remedied with the addition of more black powder on the electric match. One of the six units conditioned at +145°F failed to light and the electric match in this one also ignited, opening the end cap. This failure appeared to be as a result of insufficient restraint on the end cap. From these results it was determined that the design was reliable and the balance of 100 units could be assembled, packaged and delivered.

CONCLUSIONS

As a result of the testing and observation of the function of the Pyrotechnic Directional Light it has been determined that the unit is satifactory for the application for which it was designed; however, certain unresolved problems limit its reliability, especially at the temperature extremes. During this program, various changes were incorporated by necessity into the ignition mechanism of the unit and due to insufficient time it was not developed to a more advanced state.

It is therefore concluded that a future program should be conducted to investigate and develop a better ignition mechanism which would operate reliably at both extreme temperatures. It was also noted that changing the end cap design significantly affected the burn time; therefore, it would be advantageous to include this area in any redesign consideration.

It was also noted that there was some difficulty in packaging the unit as it was designed due to its size; therefore, the packaging should be redesigned to prevent damage to the unit during packaging or unpackaging.

FIELD EVALUATION

Sixty lights are currently being evaluated by the Ranger Department of the U. S. Army Infantry School, Fort Benning, Georgia and 20 by the U. S. Army Institute for Military Assistance, Fort Bragg, North Carolina.

Evaluation results may be obtained by contacting:

Commandant
U. S. Army Infantry School
Attn: ATSH-CD-MS-E/1LT Juckno (Autovon 835-5314)
Fort Benning, Georgia 31905

Commandant
U. S. Army Institute for Military Assistance
Attn: ATSU-CTD-TE/Maj. King (Autovon 236-7007)
Fort Bragg, North Carolina 28307

ILLUMINATION TESTS - PLUGGED END CAP DESIGN			
DATE	BURN TIME	IGNITION	TEST PURPOSE
11/9/73	56 Sec	Instant	Experimental
11/9/73	60 Sec	Instant	Experimental
11/9/73	57 Sec	Instant	Experimental
11/12/73	62 Sec	*Slow	Waterproof
11/12/73	55 Sec	Instant	Waterproof
11/12/73	52 Sec	*Slow	Waterproof
11/21/73	58 Sec	Instant	Lot Samples
11/21/73	60 Sec	Instant	Lot Samples
11/21/73	50 Sec	Instant	Lot Samples
11/21/73	52 Sec	Instant	Lot Samples
11/21/73	53 Sec	Instant	Lot Samples
11/21/73	52 Sec	Instant	Lot Samples
11/21/73	52 Sec	Instant	Lot Samples
11/21/73	50 Sec	Instant	Lot Samples

* End Cap Did Not Separate Immediately

TABLE 1

FUNCTIONAL TEST 11/23/73

ROUGH HANDLING TEST UNITS

CONDITIONING TEMPERATURE ^{o}F	5 FOOT DROP TEST	IGNITION	BURN TIME	REMARKS
-50	Horizontal	Match Only	None	End Cap Loosened
-50	Horizontal	Good	54 Sec	10 Sec Burn w/Cap On
-50	Base	Match Only	None	End Cap Loosened
-50	Base	Good	57 Sec	12 Sec Burn w/Cap On
-50	End Cap	Match Only	None	End Cap Loosened
-50	End Cap	Good	58 Sec	10 Sec Burn w/Cap On
+145	Horizontal	Instant	46 Sec	
+145	Horizontal	Good	50 Sec	11 Sec Burn w/Cap On
+145	Base	Instant	50 Sec	
+145	Base	Instant	45 Sec	
+145	End Cap	Match Only	None	Cap Ejected
+145	End Cap	Instant	47 Sec	Burned Internally

TABLE 2

Illuminant Composition	
Composition	Percentage by Weight
Magnesium, Ellipsoidal, Type 4, 30/50 Spec MIL-P-14067B	57%
Sodium Nitrate, 30 $\pm$ 15 Microns MIL-S-322 B, Grade $\bar{B}$, Class 2	38%
Laminac 4116 Plus 1.5% Lupersol DDM and 0.6% Cobalt Napthenate (6% solution)	5%
Pluronic F-68	0.5%

Blending Procedure:

1. Sieve sodium nitrate using a No. 16 mesh screen and dry at 140^{o}-150^{o}F under vacuum (20-25 in Hg) for 12 hours min.

2. Weigh out dry ingredients and hold in separate covered containers until ready for use.

3. Prepare laminac-lupersol-cobalt napthenate binder mix.

4. Pour magnesium and pluronic into blender bowl, add binder mix and initiate blender. Blend in two one minute periods. Scrape walls of bowl, muller and agitators between cycles.

5. Wearing face shield and grounding device, add sodium nitrate to mixture and initiate blending remotely.

6. Blend in two minute cycles until a damp uniform consistency is obtained. Wearing a face shield and grounding device, scrape blending bowl and agitators between cycles.

7. Store in a tightly covered velostate container until ready for pressing operation.

TABLE 3

GENERAL

General Environments Corporation / Hartwood, Virginia 22471 / (703) 752-5121

APPENDIX A

REPORT

Client: AAI Corporation
P. O. Box 6825
Baltimore, Maryland 21204

Report No. A-4694

Date 29 November 1973

Subject: Loose Cargo Test

Specifications: MTP 4-2-602, Appendix A
AAI Corporation purchase order 421450

Test Article: Four (4) wooden wirebound crates, each crate containing two (2) M2A1 Ammunition Cans. In each crate, one (1) M2A1 can was to contain two (2) live directional lights and the other M2A1 can was to contain one (1) live unit and one (1) dummy unit. Each live unit containing 200 grams of Class 'B' explosive and electric match igniter.

Test Completed: 20 November 1973

Two (2) wooden crates were preconditioned at -50°F and two (2) wooden crates were preconditioned at 145°F for a minimum of sixteen (16) hours prior to testing. The loose cargo test was conducted in accordance with the above specifications.

There was no apparent indication of damage and/or deterioration of the wooden wirebound crates as a result of the test exposure.

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APO Seattle 98749

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ATTN: Combat Service Support & Special Programs Directorate
Fort Hood, TX 76544

Commander 2
US MAC-T & JUSMAG-T
ATTN: MACTRD
APO San Francisco 96346

Senior Standardization Representative 1
US Army Standardization Group, Australia
c/o American Embassy
APO San Francisco 96404

Senior Standardization Representative 1
US Army Standardization Group, UK
Box 65
FPO New York 09510

Senior Standardization Representative 1
US Army Standardization Group, Canada
Canadian Forces Headquarters
Ottawa, Canada K1A0K2

Director 1
Air University Library
ATTN: AUL3T-64-572
Maxwell Air Force Base, AL 36112

Battelle Memorial Institute 1
Tactical Technical Center
Columbus Laboratories
505 King Avenue
Columbus, OH 43201

Defense Documentation Center (ASTIA) 12
Cameron Station
Alexandria, VA 22314

Commander 2
Aberdeen Proving Ground
ATTN: STEAP-TL
Aberdeen Proving Ground, MD 21005

Commander 1
US Army Edgewood Arsenal
ATTN: SMUEA-TS-L
Aberdeen Proving Ground, MD 21010

US Marine Corps Liaison Officer 1
Aberdeen Proving Ground, MD 21005

Director 1
Night Vision Laboratory
US Army Electronics Command
ATTN: AMSEL-NV-D (Mr. Goldberg)
Fort Belvoir, VA 22060

Commander 1
US Air Force Special Communications Center (USAFSS)
ATTN: SUR
San Antonia, TX 78243

Commander 1
US Army Armament Command
ATTN: AMSAR-ASF
Rock Island, IL 61201